Bulletin 647
Agdex 257/10

GUIDELINES FOR MACHINE-HARVESTED TOMATOES FOR PROCESSING

Editor and Contributor

Mark A. Bennett
Assistant Professor and Extension Horticulturist
Department of Horticulture
The Ohio State University, Columbus

Contributing Authors

Stanley Berry
Professor
Department of Horticulture
The Ohio State University and the
Ohio Agricultural Research and Development Center, Wooster

Stanley F. Gorski
Associate Professor
Department of Horticulture
The Ohio State University, Columbus

Dale Kretchman
Professor
Department of Horticulture
The Ohio State University and the
Ohio Agricultural Research and Development Center, Wooster

Richard K. Lindquist
Professor and Extension Entomologist
Department of Entomology
The Ohio State University and the
Ohio Agricultural Research and Development Center, Wooster

Timothy Rhodus
Department of Agricultural Economics
and Horticulture
The Ohio State University, Columbus

Richard M. Riedel
Professor
Department of Plant Pathology
The Ohio State University, Columbus

E. C. Wittmeyer
Professor Emeritus
Department of Horticulture
The Ohio State University
Ohio Cooperative Extension Service, Columbus

Contents

OCES Ohio Cooperative Extension Service
The Ohio State University

For Sale Publication

Acknowledgement

The editor expresses appreciation to Ron Overmyer, County Extension Agent, Agriculture, Sandusky County, for his review of this manuscript and to Jacquie Shepherd, Department of Horticulture, for her skilled efforts in word processing. Thanks also are extended to the many tomato producers, allied industry representatives, and processors who contributed to this bulletin revision.

2/88—1.5M (J. 51156)

Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, in cooperation with the U. S. Department of Agriculture, Frederick E. Hutchinson, Acting Director of the Ohio Cooperative Extension Service, The Ohio State University.

Guidelines For Machine-Harvested Tomatoes For Processing

Introduction

The tomato continues to be the leading processed vegetable in the United States. In 1987, for example, more than 256,000 acres of tomatoes were harvested for processing. The major states producing this crop for processing include California, Ohio, Michigan, Indiana, New Jersey and Pennsylvania with small acreages found in several other states (see Fig. 1). Ohio growers harvested nearly

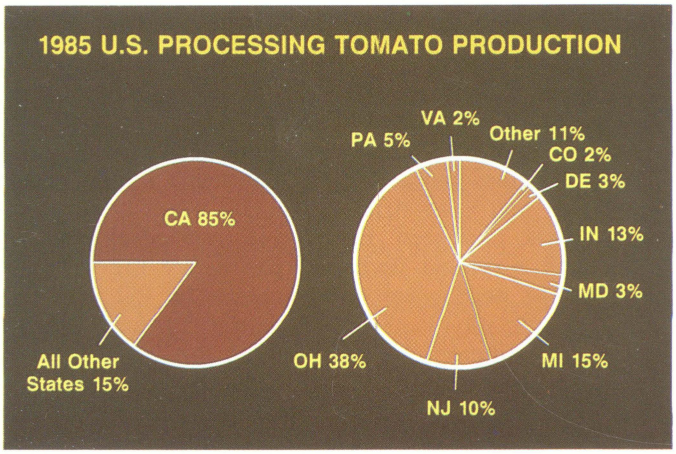

Fig. 1: 1985 U.S. Processing Tomato Production by State.

16,000 acres in 1987. Most of this acreage is located in northwestern Ohio, north of a line from Greenville to Sandusky. Ohio ranks second in the U.S. production of tomatoes for processing; California is the leading state.

Interest in machine harvesting of Ohio tomatoes started in 1960. Since then, numerous growers with clay soils and sandy soils have mastered the techniques necessary for production of machine-harvest tomatoes. Machine harvesting was the method of choice on 84% of Ohio's tomato acreage in 1986. Part of this increased interest is due to increased wages for hand harvest crews, increased cost of housing for labor crews, increased costs of Social Security and other benefits, and more governmental regulations effecting labor.

Growers who have been successful with machine harvesting emphasize that more precise cultural and production practices are required than for hand harvesting. The systems approach must be followed with machine-harvest tomatoes. Every cultural practice must be performed properly because there is a close relationship among the various practices. For example, the field selected for machine harvesting must be uniform for both soil type and drainage, good bed preparation is essential, uniform plants are needed, pests must be controlled, and other cultural practices followed on a uniform basis to make the systems approach work. In the case of hand-harvested tomatoes, exceptions can occur, but with machines, all cultural and production practices must conform to the planned system to be successful.

Production of machine-harvested tomatoes is a capital intensive enterprise. Many thousands of dollars must be invested in the harvester and the ancillary equipment to do the job. Consequently, the grower raising tomatoes for machine harvesting must be a professional tomato grower. No longer can the grower who plans on machine harvesting look at tomatoes as a secondary enterprise. A new grower just considering machine harvesting will need a minimum of 60 acres. Later on after he gains experience, he should be able to handle at least 90 to 100 acres per harvester, depending on the capacity of the harvester, availability of land, and his interest in continuing to grow tomatoes.

Successful machine harvesting requires close cooperation between the processor's field representative and the grower. This involves all aspects of production including the field selection, size of acreage, variety selection, scheduling plantings, timing application of ethephon, and decisions on when to start the harvester in the fields. Good communication between the grower and the processor's representative will produce a quality product that is profitable for both grower and processor. Profits and quality products can be achieved through "season stretching" or spreading the maturity over as long a harvest period as possible. This gives the processor and grower the longest possible time to operate their high-investment equipment.

Site Selection

Field selection is extremely important for mechanical harvesting. An ideal field would be level with uniform soil type, fertility, and tilth. The field should be well-drained with both subsurface and surface drainage systems. Land leveling should be considered where uneven drainage and topography exist.

Well-drained, sandy-loam soils are highly desirable because they become warm earlier in the spring for early planting, have fewer problems of getting a stand by seeding, and usually have less harvester down time due to excessive rainfall than clay-loam soils. However, with proper management, many Ohio growers are successfully machine harvesting tomatoes on the clay-loam soils in northwestern Ohio.

Fields that allow rows at least a quarter mile long will help reduce time lost in turning equipment at the ends of rows. Odd-shaped fields should be avoided. A north-south orientation may be desirable with direct-seeded and transplant fields to permit the use of windbreaks, thus reducing damage from strong westerly winds on sandy soils.

Crop rotation is an important consideration. This basic three-year rotation is best for successful tomato production and should be shortened only if absolutely necessary. Disease problems tend to increase when tomatoes follow tomatoes in the rotation. Tomatoes should follow, if possible, a crop with a low trash residue (e.g. rye, oats, wheat, soybeans).

Avoid following corn the previous season because of trash, high residual nitrogen, and possible herbicide residue. Tomatoes should not be planted where atrazine was used the previous year. Late harvest of corn and sugar beets may also prevent the preparation of beds in the fall on clay and clay loam soils. Soybeans and wheat appear to be good crops to plant the season previous to growing tomatoes, but be aware of possible residues from herbicides used on these crops.

Including a deep-rooted legume appears beneficial in a rotation, especially in the clay loam soils, to aid in drainage, aeration and soil structure. Fields of sandy loam soils also frequently benefit.

Growers should be extremely cautious of using fields that had soybeans grown the previous season because some of the newer herbicides used in soybeans have a very long residual and appear phytotoxic to tomatoes. Those herbicides include Canopy, Gemini, Preview, Scepter, Classic, Command, Lorox Plus and Reflex.

Soil pH also influences herbicide residues. It is recommended that Ohio soybean growers use Canopy, Gemini, Preview and Lorox Plus on soils with a pH of less than 7.1, and Classic where the pH is less than 6.9. If these materials are used on soils with a higher pH, excessive soil residues may occur.

There may be advantages of having two or more fields for the crop located several miles apart. This helps to reduce the risk from adverse localized weather conditions as well as providing different soil types to add flexibility to the production program. However, problems of moving equipment must be considered where some distance is involved.

Soil Preparation

In all types of soils, it is advisable to prepare the bed for seeding as early as possible. Early seeding is usually possible because the selected fields are the best drained soils on the farm. Well-formed beds will help surface drainage (Fig. 2). Some form of shaped bed is necessary, especially at harvest time because the bed surface must have the same profile as the harvester pick-up system. Prepare beds on standard 66-inch centers to permit use of the present harvester or a new machine or custom harvester if the year and conditions require such action. Where twin-row planting is being practiced, 66-inch centers appear more desirable.

Fig. 2: Good bed shape will assist in surface drainage after heavy rainfall.

Beds should be formed at suitable times, depending on soil type. Most Ohio soils used for tomato production can be classified as sand, silt loam, and clay loam. The sand tends to be the easiest to work and modify at all times; the silt loam is best worked in the spring; and the clay loam is typically fall plowed to accomplish good spring soil structure through winter freezing and thawing. Thus, each type tends to have a slightly different requirement.

Where selected fields contain small pot holes and other areas where surface drainage is needed, land leveling may be advantageous. Land leveling should be done in fall regardless of the soil type because the soil-leveling equipment can compact the soil.

Sand

The major concern when preparing sandy soils is to maintain adequate surface moisture and prevent wind erosion. Winter cover crops leave the soil flat in the spring for seeding and transplanting. Some successful growers have used power bedders to form the beds prior to planting. Lister shovels can be used to form wheel track furrows, and bed shaper plates are desirable for final shaping and smoothing. These same lister shovels also can be used to roughen the surface prior to an expected wind storm.

Early spring windbreaks for direct-seeded and transplanted tomatoes can be achieved successfully in different ways. One way is to strip till the fall cover crop on 66-inch centers, then seed. Early weeds and cover crop are killed with a contact herbicide just before the tomatoes emerge. The dead cover crop protects the soil until mechanical cultivation is needed to control new weed growth. Another windbreak idea is to till the soil 20 to 30 days before seeding, then sow spring oats in 33-inch rows. Shallow cultivate 6 to 8-inch tall oats before seeding tomatoes mid-way between every two oats rows. The tomatoes end up on 66-inch centers, and both oats and tomatoes can be cultivated mechanically until wind protection is no longer necessary.

Cover crops can also be sown in the drive rows and turn around areas, but this offers limited protection.

Silt Loam

Silt loam soils tend to be well drained and easy to work in the spring. Some fall land leveling may be desirable, but fall plowing and fall bed forming is usually undesirable as the soil tends to become too compact in the spring. Establish raised beds on this soil one to two weeks prior to seeding or transplanting. A rainfall on the bed is highly desirable for necessary moisture and compaction to form a good seed bed. Prior to seeding, till the top one inch of the bed for weed control. Deeper tillage may be desirable for transplanting.

Clay Loam

Clay loam soils are the most difficult soils to work early unless fall beds are prepared directly after fall plowing. The best preparation technique for fall beds has been to fall plow and disc for coarse leveling. Beds made with power tillers and shaper plates tend to do a more uniform job of distributing soil to the center of the bed than just shaper plates on a frame. The raised bed should be about 6 inches high and 42 to 48 inches wide at the top. Make furrows on 60 or 66-inch centers. The top of the bed should be as level as possible and low; avoid unfilled areas. Mid-winter preparation of "slabby" soil is acceptable if enough time is allowed for freezing and thawing to develop a desirable soil structure before spring.

A bed 6 inches high in the fall will usually be less than 3 inches high in the spring. A normal observation and mistaken decision has been that the beds should be rebuilt by again taking soil from the furrow and putting it on top of the bed. Do NOT rebuild in the spring. Fall beds can essentially be re-established to a desirable height in the spring by furrow compaction. Some growers overlap one row of a 3-row bedder so that the tractor wheels compact all furrows. The wetter the furrow, the higher the resulting bed will appear. The wetter parts of the field always have the deepest furrows.

Soil particle or clod size after bed preparation in the fall can be highly variable with clods up to 4 inches in diameter. However, by spring, the bed surface will be quite uniform in shape, and most soil particles will be no larger than ⅛ inch in diameter. After spring rains, the raised bed surface area dries more rapidly than the furrow area. Usually, a dry soil layer less than 1-inch thick forms and appears to be lying on a "moist" zone. This moist zone tends to be a uniform distance from the surface when the surface is level. Any tillage of the wet zone appears detrimental to the soil structure and soil moisture profile; however, the dry zone can be shallow tilled for weed control.

If excessive rain in the fall and winter prevents bed forming, there are two alternatives. If the spring weather is dry, beds can be made in the spring. Proper rainfall will be essential for good germination and emergence. If the spring weather is wet, beds can be made by compacting furrows with a tractor on 60-inch centers. In all cases, fall plowing or tillage is preferred.

In some years, the fall bed system will not be completed in the fall. However, advantages of fall beds, when it is possible to make them, are well worth the time and effort. Fall bed-forming requires a high commitment to early decisions for land use the following year. It also requires a significant amount of fall work and favorable weather.

The fall and spring bedding system is a form of controlled traffic tillage. No heavy equipment is ever allowed to compact the general growing area during the life of a crop. The system may also provide some surface drainage, which is advantageous for tomato seedlings and transplants as well as drainage for harvest.

Growers planning to incorporate herbicides on fall-made beds should work the beds as early in the spring as possible. This will result in beds that are properly shaped for good herbicide incorporation and still maintain the desired bed shape.

Fertilizer and Lime Program

Fertilizer programs have much influence on the success of machine harvesting (Tables 1 and 2). Uniformity of fruit maturity is affected by fertilizer programs, especially the use of nitrogen. Ideally, the nitrogen for the crop should be mostly depleted when most of the fruits start to turn red. To accomplish this, avoid heavy applications of nitrogen to tomatoes that are to be machine harvested. Sometimes where tomatoes follow corn or legumes on heavy soils in the rotation, the nitrogen carryover can cause excessive vine growth.

Table 1: Fertilizer Recommendations for Processing Tomatoes on Silt Loam to Clay Loam Soils

	Lbs/A	
Soil Test - lbs/A	P_2O_5	K_2O
Less than 100	175	–
Above 100	125	–
Less than 200	–	300
Above 200	–	200

Table 2: Fertilizer Recommendations for Processing Tomatoes on Sandy Loam Soils

	Lbs/A	
Soil Test - lbs/A	P_2O_5	K_2O
Less than 100	150	–
Above 100	100	–
Less than 200	–	350
Above 200	–	250

Lime Needs

Take a soil sample from the field to be planted to tomatoes as early as possible. There are various laboratories, including the REAL Laboratory at the Ohio Agricultural Research and Development Center, Wooster, where a suitable soil analysis can be made. County Extension offices can supply information on the procedures to follow in taking soil samples.

The importance of soil pH in relation to fertilizer efficiency cannot be over emphasized. Correct the pH first, then apply the fertilizer. Apply sufficient limestone (apply 6 months in advance) to maintain a pH 6.5. Many soils in northwestern Ohio have the soil pH in this desirable range; a soil test will deterine need for limestone. Maintain soil pH in desirable range (pH 6.5) so that most micronutrients as well as major nutrients will be most readily available.

Direct-Seeded Plantings

The soil test will give some indication as to the quantities of P_2O_5 and K_2O to be applied. Apply most of the P_2O_5 and K_2O prior to plowing or field tillage. Band placement of some P_2O_5 at planting may be advantageous, especially under cool conditions. If soil tests are not available, an application of 125 pounds of P_2O_5 and 250 pounds of K_2O per acre should be suitable for most soils in northwestern Ohio except for the light-textured soils (sandy loams) where additional K_2O may be needed.

Some growers have successfully used the Purdue University method of applying a dilute solution of 10-34-0 on the seed at planting time. For use on seed, mix at rate of 1 pint of the 10-34-0 liquid fertilizer to 4 pints of water, and apply the diluted solution at a rate of 1 pint per 100 feet of row. With sandy soils, use at one-half the rate suggested.

Other growers have successfully applied fertilizer, high in phosphorus, in bands 2 inches to the side of and about 2 inches below the seed. Apply no more than 10 pounds of N, 40 to 50 pounds of P_2O_5, and 10 pounds of K_2O per acre in band(s). A band of high-phosphorus fertilizer one to two inches below seed will help greatly.

Most growers should use a nitrogen rate for direct-seeded tomatoes that is less than for transplants. Check with processor's field representative for specific suggestions. The seasonal total should range between 30 and 70 pounds of N per acre, depending on soil type, previous crop, general soil fertility level, and variety being grown. Past experience in growing tomatoes for machine harvest will help to indicate the N application for specific soils and variety types. On silt loams, loams and clay loams, the fertilizer may be applied before plowing. On sandy soils, about 25 percent of the N may be applied as a sidedress application. Contact processor's field representative for experiences regarding sidedress application for specific varieties.

Transplants

A soil test will help to determine amounts of P_2O_5 and K_2O to apply. This fertilizer, along with nitrogen, should be applied before plowing except with sandy soils, where some nitrogen may be applied as sidedress application.

If no soil test has been made, a typical application on the loams, clays, and clay loams would be approximately 125 pounds of P_2O_5 and 250 pounds of K_2O per acre. (Check with processor's field representative for specific suggestions.) The nitrogen rate would be 60-120 pounds per acre. Additional K_2O may be needed on the sandy and light-textured soils (Table 2).

Apply a starter fertilizer high in phosphorus at planting time. Typical analyses include 21-53-0, 10-52-17, 10-55-10. Follow the manufacturer's directions, which are usually about 3 pounds of the fertilizer in 50 gallons of water with ½ pint of solution per plant. Liquid fertilizers such as 10-34-0, 8-16-8 and similar analyses can be used if diluted. One quart of liquid fertilizer per 50 gallons of water is equivalent to about 2.75 pounds per 50 gallons. With higher plant populations, more starter fertilizer will be needed per acre as compared with lower populations used in hand harvested fields.

Because uniformity of maturity is so important, methods of applying fertilizer can be important. Avoid overlapping fertilizer swaths because this can cause uneven growth of tomato plants.

The major challenge in planning a fertilizer program for transplants is the nitrogen rate. When machine harvesting was started in Ohio, growers were using high rates of N. These high rates delayed maturity, caused excessive vine growth, and frequently reduced yields of machine-harvested tomatoes. Only sufficient N should be present for early plant establishment and early fruit development, plus enough to maintain plant vigor. Some of the determinate, early-maturing varieties may require more nitrogen than late varieties to obtain fast plant growth before fruit setting occurs. Growers should discuss this phase of the fertilizer program with the processor's field representative. Probably no more than 70 to 100 pounds of N per acre will be needed in most situations. Where tomatoes are following heavily fertilized crops, less nitrogen (60 pounds or even less) may be needed.

Micronutrients

Manganese deficiency may occur in some high pH soils in northwestern Ohio. This can be corrected by spraying with manganese sulfate ($MnSO_4$ or epsom salts) at 4 to 5 pounds of the chemical per acre. Thoroughly cover foliage with a minimum of 50 to 60 gallons of solution.

Some growers and processors apply borax on fields intended for tomatoes. Plant analyses have indicated fields that may be in the low to deficient zone. One half to one pound of boron per acre, applied as broadcast application, will meet the needs of a tomato crop.

Plant Analysis

Growers can have leaf samples analyzed at the REAL Laboratory, Ohio Agricultural Research and Development Center, Wooster, Ohio 44691. Kits can be purchased at county Extension offices. These analyses, if made in late June and again just prior to harvest, will give important information on which to make changes in future fertilizer practices. Information on sampling procedures is available from county Extension offices. These plant analyses can give important information on adequacy of major and micronutrients.

Irrigation

Few Ohio growers have invested in irrigation for production of processing tomatoes. Part of this reluctance has been due to difficulty in finding an economic source of water. Also, there has been some uncertainty on the expected yield increases from irrigation. Growers raising tomatoes in the light-textured soils (sands, sandy loams and similar soils) should consider irrigation. Growers in heavier soils can profitably use irrigation to improve the production of tomatoes for machine harvesting. From a long-range viewpoint, irrigation will help all growers raising tomatoes for machine harvesting if the following management practices are observed:

1. An adequate moisture level is necessary for seed germination, seedling emergence, early plant growth, fruit set and early fruit enlargement. If moisture becomes a limiting factor during any of these periods, uniformity of fruit maturity cannot be attained.
2. With direct-seeded plantings, apply ½ inch of water, using a slow application rate, if rain does not occur following seeding. The application of water during this period will reduce the soil crusting problem. Continue to irrigate the plantings as needed.
3. Another critical period for soil moisture is from just prior to the time the blossoms open through the time of fruit set. Use irrigation at this critical period if rainfall is inadequate. Following fruit set, variations in soil moisture can cause blossom end rot. Careful use of irrigation during the rapid enlargement period can help to reduce the blossom end rot problem.
4. Irrigation immediately following transplanting can help to reduce transplanting shock. A light application of water—½ inch, for example—at this time can help to insure a uniform stand. This is especially important for growers using smaller cell or plug-type transplants.
5. Irrigation can also improve the effectiveness of surface-applied herbicides such as diphenamid (Enide), chloramben (Amiben G), and metribuzin (Sencor or Lexone).
6. Irrigation should be discontinued when ripening starts. Too much water, either rain or irrigation, during the

ripening period will reduce the fruit quality. Do remember that ethephon is best applied to plants that are in a normal, turgid condition.

7. In planning an irrigation program, do not apply excessive amounts of water at any time. Usually an inch of water per week is needed during fruit enlargement, while ½ inch per week is adequate prior to this state. Plan your program so there will be a safety factor—in case rain occurs soon after irrigation. Also consider timing of irrigation and management of foliar diseases.

8. An irrigation system can be used for frost protection, but solid set is needed. For specific suggestions, contact the Department of Agricultural Engineering, The Ohio State University, 590 Woody Hayes Drive, Columbus, OH 43210.

Variety Selection

A tomato variety must meet several requirements to be suitable for machine harvest. Most important, the fruit should be sufficiently firm and tough-skinned to withstand machine and bulk handling. Growers should work closely with the processor's field representative in selecting varieties.

Selected varieties should be capable of setting fruit uniformly over a wide range of temperature conditions to insure concentrated fruit set and a high percentage of ripe fruit recovery. Additional requirements include small plant growth habits, concentrated flowering, good fruit-setting ability, uniform ripening, ability of ripe fruit to store on the vine and then separate freely from the plant without stems, and be resistant to fruit cracking. These factors affect the efficiency of machine harvest. Varieties should be resistant to Fusarium and Verticillium wilts as well as having tolerance to Sencor and Lexone. Use varieties with a succession of maturities, particularly early varieties, so harvest peaks can be spread and delivery gluts avoided.

The processor's needs must be considered in variety choice because of quality requirements for different products being manufactured such as juice, soup, catsup, sauce, and paste. This becomes critical in production for wholepack and diced canned tomato production where stem scar and core must be small enough to pass coreless raw product standards, and fruit-peeling characteristics must be suitable for automated steam or lye peeling.

Stand Establishment

Transplants and Transplanting

Transplanting is much more costly in time, labor and equipment than seeding but is necessary to have early fields for harvest. Most growers use bare-root plants. Use only good quality "certified" plants. They should be stocky, uniform in size and age, and properly hardened. Sorting may be necessary to remove excessively large or small plants to improve plant uniformity for more uniform ripening.

Container-grown plants may also be used for planting. However, research in Ohio has indicated no advantage of these specially produced plants over good quality southern field-grown or northern bare-root greenhouse plants. Container-grown plants may store better if adverse conditions prevent timely planting.

Row spacing should be determined by harvester and other equipment being used (Fig. 3). Within-row spacing should be from 9 to 10 inches, depending somewhat on variety. Some early, small vine-type varieties should be grown in twin rows to give adequate yields. Twin rows can be 16 to 20 inches apart on beds spaced on 60 to 66-inch centers and within-row spacings should be no less than 12 inches. Remember that special transplanting and cultivation equipment is necessary for twin-row culture. Vine training may be required for some varieties. Growers just starting to produce for mechanical harvest should consider only a small acreage of twin rows to gain experience in this more management-demanding production system.

Fig. 3: Tomato transplanting equipment planting 3 twin rows.

Transplanting usually starts near April 20 to May 1 in Ohio depending on weather conditions and the consideration of risk of frosts in early May, which may require replanting. Generally, there should be three or more plantings, a week to 10 days apart and with three or more varieties, so that not all fields will ripen at once. Consult with your field person on planting schedules. Planting can continue until June 10 to 15, if necessary, to have an extended season and if seeded fields will not provide for late-season harvests.

Field Seeding

The ideal system for complete mechanization of processing tomato production would be field seeding of the entire crop. However, most growers have not yet developed the techniques and confidence in seeding to plant the majority of their machine-harvested acreage by this method. Further, varieties and cultural methods have not been developed that will result in fruit ripening as early from seeded as from transplant crops. Season stretching is important and, consequently, transplanting will still be necessary in Ohio's industry.

Stand establishment from seeding vs. transplanting can save considerably in time and labor costs, reduce chance of disease introduction with transplants, and gives greater flexibility in time of planting, variety selection, and plant populations. However, stand establishment by seeding has not been widely adopted, chiefly because of difficulties in emergence on the clay-loam soils, weed-control problems, and later maturity. Methods and equipment are available to greatly improve the odds of obtaining a satisfactory stand by seeding, and weed control can be satisfactory with proper management and field selection. For persons who have only used transplants, it is difficult to develop the patience and confidence necessary to allow time for a seedling to emerge and develop. A 90 percent survival is usually the minimum acceptable limit for a satisfactory stand with transplants, whereas a 50 to 70 percent stand is satisfactory for seeded fields because the closer spacing and the vigorous growth of seedlings will fill in blank spots more readily than transplants.

Seeding System

Successful seeding depends on a complete system of seedbed preparation, precise placement of seed and starter fertilizer, use of an anti-crustant, and proper compaction of the soil around the seed.

Seedbed preparation is covered in the section on Soil Preparation. Keep in mind that seed should be placed at a uniform depth in uniformly warm, moist soil. The seedbed must be relatively firm to accomplish uniform seeding and achieve the uniform emergence, growth, and development necessary for a favorable once-over harvest. However, excessive seedbed preparation is not needed as this may increase the crusting problem.

A seeder must have a means of accurately controlling planting depth. Planters with wheels in front and behind the seed furrow shoe usually do the best job in controlling depth. The furrow shoe is usually adjustable to set the depth. Successful plantings can be obtained by seeding ⅝ to ¾ inches deep. The seed-feeding mechanism should drop 4 to 7 seeds per clump in the firm, moist soil behind the base of the shoe. The feeder tube should be designed to prevent soil from plugging the tube when operator is setting the equipment at the start of a row. Spray a liquid starter fertilizer on the seed (see section on Fertilizer).

Use an anti-crustant on the clay-loam soils in Ohio. Some planters place the anti-crustant just over the seed clump, and others fill the seed furrow (Fig. 4). Regardless

Fig. 4: Field seeding system with vermiculite to prevent crusting.

of the type used, there should be sufficient material to completely fill the seed furrow above the seed. This may require as much as 22 to 24 cubic feet of material per acre of the continuous feed types of planters (Fig. 5). Apply the anti-crustant with a positive-feed mechanism.

Fig. 5: Field seeding equipment with belt seeder and large hopper for vermiculite.

Horticulture-grade vermiculite, Perlite, and composted sawdust have all been used successfully. Do not use fresh sawdust and ground corn cobs because of the possibility of toxic compounds that will kill the seedlings.

Soil should be firmed around the seed from the side with some type of wheel. The split press wheel should also form a small ridge of soil and anti-crustant over the seed row to prevent soil from washing into the row. This soil over the row will usually crust and prevent emergence. Flat press wheels form a depression that fills with soil from a heavy rain and prevents emergence, even though an anti-crustant is used.

Plant Spacing (Single-row culture)

A usual row spacing of 60 or 66 inches is dictated by the wheel spacing of the harvester and the tillage equipment. Determine precise row spacing after discussion with a harvester company representative. Clumps of 4 to 7 seeds each should be on 6- to 9-inch spacings depending somewhat on variety and soil fertility. This will result in a desirable 4 to 5 plants per clump that should not be thinned. About 8 ounces of seed per acre is required depending on seed size, viability, and the degree of de-fuzzing of the seed. Use de-fuzzed seed.

Plant Spacing (Double-row culture)

Twin rows usually give higher yields due to more uniform ripening. However, this type of culture requires considerable management of the entire system from bed preparation to harvest and is recommended for experienced growers only. Seedbed preparation is critical for uniform seeding depth and uniform emergence. Row spacings must be constant to permit cultivation and weed control operations. Row spacings of 16 to 20 inches between rows and 9 to 12 inches between clumps within each row usually provide the most desirable response. Twin row culture appears better adapted to 66-inch beds and the use of small vine-type varieties. Use of herbicides for weed control is critical because cultivation is more difficult and requires more specialized equipment than for single row culture. The usual rapidity and uniformity of fruit ripening requires good harvest management for optimum results. Vine training may be needed with double row culture.

Time of Seeding

Seeding in Ohio should be done between April 20 and May 20. Before April 20 the soil is usually too cold, and a frost may seriously damage a good seeding. After May 20, the crop may not mature because 110 to 125 days are needed for full maturity depending on variety. Be sure to check with processor's field person on this matter. A temperature of 55°F at the 1-inch depth at 1:00 p.m. is considered minimum for seeding.

Consider the seeded crop only for the mid- and late-season crops with transplants providing the early crop. Be sure to consult with processor's field person on varieties and a planting schedule to maximize the length of the harvest season. In all cases, be patient during seedling emergence. Cold, dry soil will delay emergence possibly up to 30 days. Seeds will usually survive unless serious crusting occurs. Any stand above 50 percent emergence, if uniform, should be saved.

Pre-Germinated Seeding

Pre-germinated seed prior to planting usually results in earlier, more uniform emergence. Two methods are used: "plug-mix," and "gel" seeding.

The more reliable method for obtaining a stand from field seeding is to pre-germinate the seed, mix the seed with an artificial medium that will serve as an anti-crustant and source of nutrients for the small seedlings, and then plant a "plug" of this mixture. This has been referred to as "plug-mix planting." A mixture that has been sucessfully used:

1 bu. of Peat Lite Mix*
½ lb. of Magamp (7-40-6, med. granules)
½ oz. tomato seeds
3 to 4 qts. of water to moisten the mix slightly

One bushel of this mix will plant about 600 clumps using ¼ cup per plug.

*Commercially available as Jiffy Mix, Redi-Earth, and possibly others Jiffy-Mix has the Magamp in the commercial mix

Seed can be germinated by mixing the desired amount of seed in moist vermiculite in a plastic bag and placing this in an area where temperature is about 80°F for 48 hours. Germination can also be done in the peat-lite mix, but if adverse weather occurs and planting cannot be done, it is easier to store a small bag of germinated seed than a large volume of mix. The seed-vermiculite mix can be kept for 5 or 6 days at 40°F. If longer storage is required, it is best to germinate another batch.

The germinated seed-vermiculite mix and the peat-lite medium can be mixed with a rotating cement mixer, a screw-type feed mixer, or other type of good mixer. Thoroughly mix prior to adding the water. Use only enough water to make the mix slightly moist. Excess water will prevent the mix from feeding properly in the planter.

A planter is available from the Mechanical Transplanter Company, Holland, Michigan, but this machine is rather slow and may require considerable maintenance to keep it in good working order. Some growers have also developed their own plug-mix planters. One of the most critical aspects of this method of seeding is proper depth placement and compressing the soil around the plug from the side so that a slight amount of mix is at the soil surface to serve as an anti-crustant. Shallow planting and improper compaction will result in drying of the plug and the wind blowing it away. Excessively deep planting will allow soil to wash over the plug and crusting may result, which will restrict emergence.

Some growers over-seed using approximately one pound of seed per acre in continuous row and then thin to a desired stand. No anti-crustant is used because the seedlings tend to assist each other in emerging through a crust that may have formed. This practice may become too costly when hybrid seed is used.

"Gel" Seeding

This method consists of pre-germinating seed in cloth bags in aerated water and then suspending the seed in a gel. The mixture of seed and gel can then be pumped through a plastic tube into a seed furrow. A peristaltic impulse pump can be used to force the mixture out of the tube without seriously damaging the tender germinated seed. Because of the precise conditions necessary for pre-germinating the seed, this is probably best done by a person or company set up to do this on a custom basis. Several gel-forming materials are on the market. Some are toxic to seedlings, some are unstable and some are difficult to dissolve in water.

Weed Control and Cultivation

Efficient operation of the tomato harvester requires weed-free fields at harvest time. Weeds, especially foxtail and nutsedge, slow the harvester and make it difficult to harvest the crop satisfactorily. Where perennial weeds are a problem, the grower should try to control these weeds in the rotation before tomatoes are planted. For specific suggestions on perennial weed control, see the Ohio Agronomy Guide and the Ohio Vegetable Production Guide. Copies are available from county Extension offices. Fields selected for tomatoes should not have received more than 0.75 lbs ai/A atrazine (lower rates if not a spring application), or other long-lasting herbicides, within the past year.

Mechanical Cultivation

A combination of chemical weed control and cultivation is usually needed to control weeds and to maintain bed shape. Weeds may emerge after herbicides have been applied. Such weeds should be destroyed by cultivation. Uses of various types of knives for shallow cultivation will not destroy the effectiveness of soil applied preemergence tomato herbicides (e.g. diphenamid, chloramben, pebulate, and trifluralin).

Chemical Weed Control

Much progress has been made in recent years in chemical weed control programs. When applied at the proper time and with properly calibrated equipment, approved chemicals give acceptable weed control. Poor results are usually due to improper application, poor timing in relation to rains, inadequate records on specific weed populations, inadequate rates of herbicide for particular soil types, and poor follow-up of cultivation. Where incorporation is needed, attention should be given to selection and adjustment of equipment. Check with the processor representative or OCES for restrictions on the use of any herbicide before application.

Weed Control in Transplanted Tomatoes

Apply 1 to 2 pints of Treflan 4EC per acre and incorporate immediately into the top 2 to 3 inches of soil. Use lower rate on sandy soils and up to 2 pints on heavy soils. Expect poor weed control when applied to wet areas. Stunting and yield reduction may result if weather is cool and damp.

Where yellow nutsedge (nutgrass) is a problem, use Tillam. Apply ⅓ to 1 gallon of Tillam 6E or 40 to 60 pounds of Tillam 10G per acre pre-plant. Incorporate to a depth of 2 to 3 inches immediately after application. Use lower rate on sandy soils and up to one gallon on heavier soils. Apply on well-worked soil that is dry enough to permit thorough mixing. Do not use Tillam as a preplant treatment on direct-seeded tomatoes.

Tillam may be applied post-transplanting. Apply either ⅓ gallon per acre Tillam 6E as directed spray to the soil or broadcast 40 pounds of Tillam 10G per acre when plants are dry. Incorporate to a depth of 2 to 3 inches immediately after application. Do not apply within 8 days of harvest. Tillam may be applied at layby on direct-seeded tomatoes. See label for details.

Enide may be used with transplants either as pre-transplanting or as post-transplanting treatment. See Section on Field Seeding and the Enide label for details.

Sencor or Lexone may be applied as a pre-transplant treatment. Numerous formulations are available, i.e., 50WP, 4F, 4L, and 75 DF. Therefore, rates are given in pounds of active ingredient per acre (lbs ai/A). Calculations must be made to convert to application amounts of your formulation. Apply ¼ to ½ lb ai/A to the soil and incorporate to a depth of 1 to 2 inches. Materials may be tank mixed with Treflan and applied pre-plant incorporated with transplants only. Follow all label directions and precautionary statements.

Sencor or Lexone may be used on direct-seed or transplants after plants have reached the 5 to 6 true-leaf stage or when transplants have recovered from transplanting shock. Apply ¼ lb ai/A of Sencor or Lexone in single or multiple applications with a minimum of 14 days between treatments. Do not apply within 7 days of harvest. Do not apply more than 1 lb ai/A of Sencor or Lexone during one crop season. Be sure to read the label precautionary statements. Do not apply within 3 days after periods of cool, wet or cloudy weather or crop injury may occur.

Amiben 10G can be used on transplants after the transplants are established, or at layby with either transplants or direct-seeded tomatoes. The field must be weed free when Amiben 10G is applied. Foliage must be dry. Use 30 to 40 pounds of Amiben 10G per acre. Many Ohio tomato fields have a serious problem with black nightshade. Amiben does an acceptable job of controlling this problem weed.

Weed Control in Field-Seeded Tomatoes

Apply 3.3 to 6.6 pounds per acre of Enide 90 WP as a preplant incorporated treatment immediately after seeding as a preemergence treatment. Use the higher rate on heavier soils and for better control of many broadleaf weeds. On reshaped beds, a direct spray of up to 3.3 pounds of Enide 90 WP when plants are 5 to 6 inches tall, may be helpful. Do not apply more than 6.6 pounds of Enide 90 WP per acre in one season. Enide can be used up to 1 month after seeding. Where Enide is incorporated, depth of incorporation should be 4 to 1½ inches. Enide is subject to leaching, and if heavy rains occur, weed control may not be satisfactory, and injury may occur to seedlings under cool, wet conditions.

Devrinol may be used on either direct seeded or transplanted tomatoes. Apply 2 to 4 pounds per acre of Devrinol 50 WP as a preplant incorporated treatment. Use the lower rate on light soils (coarse textured - sandy) and the higher rate on heavy soils (fine textured - clay). Devrinol should be thoroughly incorporated into the soil to a depth of 1 to 2 inches or shallower. Deeper incorporation of Devrinol will result in loss of weed control. The residual from Devrinol is long lasting; therefore, a deep moldboard or disc plowing must be done prior to planting of succeeding crops. Do not seed alfalfa, small grains, sorghum, corn, lettuce or sugar beets in Devrinol treated soil for 12 months after treatment.

The amount of Devrinol residual can be reduced by making a band application (10 to 14 inch band) instead of a general broadcast application. Area between the rows should then be kept weed free by cultivation until the seedlings are large enough to receive a postemergence treatment. Sencor or Lexone (metribuzin), or Amiben G should then be applied.

If weeds emerge before tomatoes, apply one quart of Gramoxone in 50 to 60 gallons of water per acre just before the tomato seedlings emerge. A non-ionic surfactant must be used as directed by the label. Gramoxone will kill all emerged plant seedlings including tomatoes. Observe label for safety precautions.

Many Ohio tomato fields have a serious problem with black nightshade. Amiben adequately controls this problem weed. Amiben 2 SC or 75 DS may be applied at the time of seeding. Apply 2 to 3 lbs ai/A immediately after seeding. An activated carbon protection system must be used to protect the tomato seed. Thoroughly mix 1 lb of activated carbon with each cubic foot of number 2 or 3 horticulture grade vermiculite. Apply 1 cubic foot of this mixture per 600 feet of seeded row by filling the seed furrow with this mixture (15 cubic ft/A). Use a positive-feed applicator to deliver this mixture to the seed furrow directly ahead of the planter press wheel.

Granular Amiben may be used after field seeded tomatoes have reached the 5 true-leaf stage. Apply 30 to 40 pounds of Amiben 10G per acre. Foliage must be dry and the field must be weed free. Do not use on sandy soils. Results may be erratic if rains (or irrigation) do not occur soon after application.

Sencor or Lexone can be applied on established plants after they have reached the 5 to 6 true-leaf stage. Numerous formulations are available, i.e., 50WP, 4F, 4L, and 75 DF. Therefore, rates are given in pounds of active ingredient per acre (lb ai/A). Calculations must be made to convert to application amounts of your formulation. Use ¼ to ⅜ lbs ai/A of Sencor or Lexone in 20 to 75 gallons of water. Do not apply more than 1 lb ai/A of Sencor or Lexone in one season. Follow manufacturer's label for special precautions. Do not apply within 3 days after periods of cool, wet or cloudy weather or crop injury may occur. Some varieties may be injured by Sencor or Lexone. Most varieties may be treated with ¼ lb ai/A without injury. This herbicide controls many broadleaf weeds such as velvetleaf, redroot pigweed, venice mallow (flower-of-the-hour), common purslane, and jimson weed.

Important Reminder: With all pesticides, accuracy of application is important. Do not exceed label (or recommended) rates of application. Application equipment must be in good mechanical condition so that proper rates of pesticide can be applied after calibration of equipment. Excessive use of pesticides can result in residues in the harvested fruit. Be sure to follow label (or recommended) rates.

Cultivation and Bed Management

Some form of mechanical cultivation is necessary to control weeds and maintain soil aeration. Bed forming and re-shaping can usually be done in the same process (Fig. 6). Cultivation must start early when the weeds are small.

Fig. 6: Cultivating tomatoes and re-shaping beds in one operation.

As the harvest season approaches, the bed surface must conform to the same profile as the harvester pick-up. Any clods or ridges left on the bed surface will go into the harvester and cause problems—especially in a wet fall.

Power tiller cultivators tend to work best. Power tiller rotational speeds should be kept as slow as possible on clay soils. Lister shovels are used to dig the furrows out, and shaper plates should always follow the tiller tools. The use of a sled bedder with various shaping devices can also be used to maintain bed shapes. It is common on all soil types to rip a narrow slot down the wheel track furrows after or during the last cultivation. These slits are up to 6 to 8 inches deep and are made to get through a compacted layer and dispose of excess surface water after heavy rains.

Tillage equipment should be adjusted so that injury to the root system is avoided. Root pruning prior to or during flowering can cause significant blossom drop. Root pruning during fruit enlargement can result in blossom-end rot.

Disease Control

The concept of a systems approach was discussed in the introduction of this manual. Disease control is an important integral in that approach. The grower should closely follow spray recommendations given in latest OCES Bulletin 672, Ohio Vegetable Production Guide, and recommendations from the processing company field persons.

Mechanical vs. Hand-Picked

Major cultural practice and varietal changes accompany the shift from hand-picked to mechanical harvesting. Following is a preview of these changes and their possible influences on disease development:

A. Fall Plowing and Bedding:

These aid in disease control. The overwintering capacity of most disease organisms is reduced if infested tissue is thoroughly worked in the soil prior to winter.

B. Shift from Direct-Seeding to Transplants:

The early season appearance and severity of some diseases are associated with the use of transplants. Direct-seeding can reduce the occurrence and early appearance of foliar diseases—early blight, Septoria, late blight and certain bacterial diseases.

There will probably not be any effect on severity of fruit rots. Producers can expect some damping off and root rot problems with direct seeding.

C. Increased Plant Populations:

With increased plant density, thorough fungicide spray coverage will be more difficult. Greater attention must be paid to sprayer calibration, perhaps increasing gallonage and penetrating the lower leaves in dense plant canopy.

D. Rotation Practices:

Producers will shorten rotations on better sites. Most diseases increase if rotation intervals are shortened. This will be particularly true with fruit rots and wilts.

E. Delayed Harvests

Fruit rots are expected to increase with mechanical harvest. The major reason is that ripe fruit, which is more susceptible to rots, may be held in the field longer.

Important Tomato Diseases in Ohio

Foliar Diseases

Major foliar diseases in Ohio are early blight, bacterial speck and spot, Septoria leaf blight, and late blight (Figs. 7 & 8). Symptoms of these diseases can be very similar, making identification difficult. Early identification is extremely important as control strategies will differ depending on the disease. Help in identifying diseases is available by sending samples to the OCES Plant and Pest Diagnostic Clinic, 110 Kottman Hall, 2021 Coffey Road, Columbus, OH 43210. Contact your county Extension office for details.

Fig. 7: Early blight symptoms on tomato.

Fig. 8: Septoria leaf blight on tomato.

Control of Foliar Diseases:

1. Reject transplants with disease symptoms.

Southern grown transplants can carry diseases that will be difficult to control by later fungicide sprays. Therefore, early application of appropriate fungicides is necessary.

2. Spray with fungicides at regular intervals.

Follow the suggestions contained in OCES Bulletin 672 or recommendations from processor's field persons. Shorten spraying intervals during the period of rapid plant and fruit development. During wet weather, many tomato diseases increase in severity. Major reasons for these increases are: 1) fungicide wash off, 2) rapid growth of new leaves unprotected by fungicides, 3) difficulty to adhere to spraying schedules, and 4) rapid development and spread of pathogens. To protect plants during these periods, it is advised that growers reduce their spray intervals to seven days and, under extreme weather conditions, five days.

3. Apply sufficient nitrogen to grow moderately vigorous plants.

Premature nitrogen and potassium deficiency increases disease susceptibility.

4. Rotate tomatoes on a three-year schedule.

Fruit Rots

Because fruit rots reduce yield and adversely affect harvesting, they are a concern to the grower. Processors are equally concerned about fruit rots. Processors have to conform to state and federal health agency standards concerning the amount of mold in products. If this amount is exceeded, the processed products may be unsalable. Fruit rots, and in particular anthracnose, are the major contributors of mold in the products (Fig. 9). To prevent these problems, processors set standards limiting the amount of fruit rots in tomatoes entering the plant. If this amount is exceeded, the load may be rejected.

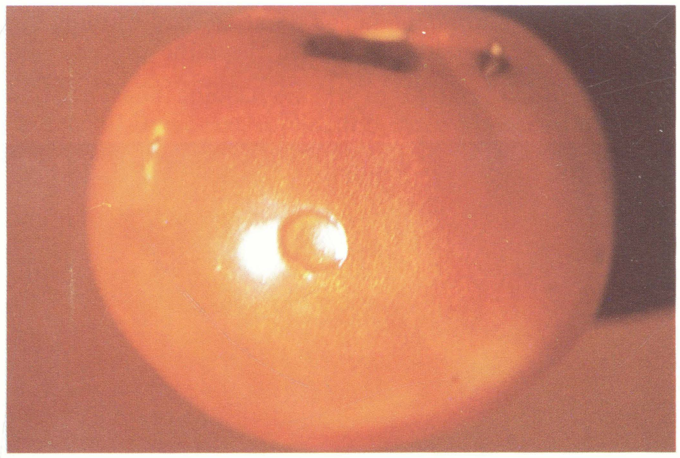

Fig. 9: Anthracnose tomato fruit rot.

Anthracnose is the most important fruit disease and requires early protective sprays. The extent of anthracnose development depends on soil type, previous cropping, variety, general nutritional level and the extent of defoliation by other diseases. Fruits on plants with sparse foliage are usually more subject to infection than are those with good leaf cover. The fungus can attack green fruit. It enters the fruit wall and remains dormant until the fruit begins to ripen. Once within the fruit, the fungus is protected from fungicides. Also, the fungus can increase in young foliage injured by flea beetles and foliar diseases. This emphasizes the importance of early season protection.

Early and late blight attack both foliage and fruit. Late blight rot usually is found on the fruit whenever present on the foliage. Early blight frequently causes severe defoliation without causing fruit rot. Early blight appears on the foliage every year in Ohio, whereas late blight seldom occurs. Buckeye fruit rot occurs sporadically, usually in localized areas. The same is true of Rhizoctoniasoil rot, and both are favored by flash rains that temporarily flood the soil surface.

Control of Fruit Rots:

1. Follow a regular spray program.

Start early, perhaps 2 to 3 weeks after transplanting or after emergence of seedlings. Continue program at 7- to 10-day intervals until harvest. Late season protection is important because anthracnose can be severe. Bravo 500 and Dithane M-45 or Manzate 200, give excellent control of anthracnose.

2. Apply fixed coppers mixed with other fungicides.

Three or four sprays may be necessary, starting 1 to 3 weeks after transplanting or seedling emergence.

3. Use treated seed.

These diseases may be seed borne.

Summary of Disease Control Programs

1. Follow a three-year rotation. Do not plant following potatoes or peppers.
2. Do not save your own seed.
3. Use only certified transplants.
4. Start early and follow a regular spray program. In the first three or four sprays, add a copper fungicide to protect against bacterial diseases. As harvest time approaches, some growers believe that the crop is "made" and additional fungicide sprays are unnecessary. However, it is during this period that unprotected tomato foliage and fruit are most susceptible, and, if wet weather occurs, disease development can be severe. It is, therefore, strongly advised that fungicide sprays be continued until harvest, even after application of ethephon.
5. Adjust and calibrate sprayers to give good, uniform coverage with a minimum of drift.
6. Check fields on a regular basis. Report unusual problems to OCES/OSU personnel and processing company representatives. Follow latest state and/or company recommendations.

Insect Control

In Ohio, there are few constant insect pests of tomatoes such as flea beetles, Colorado potato beetles, cutworms, loopers, fruitworms, and aphids (Fig. 10). These pests are well-known to most producers, and are easily recognized. The following section is intended to remind you of some common sense procedures to follow when designing an insect pest management program for processing tomatoes.

As most producers and field persons know, insect control is not magic, and depends on several factors, including: 1) early detection of pests and/or pest damage, 2) proper pesticide selection and application, and 3) pesticide rotation to minimize the rapid development of resistance and to ensure that the entire range of pests attacking the crop will be controlled.

Fig. 10: Colorado potato beetle injury to tomato fruit.

Early detection depends upon thorough scouting of fields, using light and/or pheromone traps, and paying attention to weather developments. There is no reason to treat fields when pests are not present and—just as bad—not to treat when necessary. The OCES operates a series of light and pheromone traps throughout the state, and issues weekly reports in the IPM Newsletter. Paying attention to what is happening statewide could help you become aware of coming pest invasions.

Proper pesticide selection and application are very important. The latest recommendations are found in OCES Bulletin 672, the Ohio Vegetable Production Guide. Often, processors have specific policies concerning pesticide use for their growers. These should be observed, but remember that the label on the pesticide container is the ultimate authority. Proper application is sometimes difficult. High plant populations result in denser plant canopies that make spray coverage more difficult. Many of our currently recommended pesticides do not have systemic activity and must contact the pests or be placed where the pests will come into contact with residues. Pay attention to temperatures when using pyrethroids. Some may be less effective when temperatures during and after application are above 85°F.

Do not depend on one material to do the job, no matter how effective it is. Change to a material of another chemical class occasionally (e.g., monthly). This may help to reduce the development of pesticide resistance. The development of new pesticides has slowed during the past several years. Do not use any more material than necessary.

Ethephon as a Ripening Aid

Ethephon is a plant regulator that, when applied to tomatoes, results in an increase of ethylene in the tissues and triggers the ripening action of mature green fruit. Ethephon should be considered as a useful management tool in a complete production program. Advantages for the use of ethephon for machine harvest include the following:

1. It hastens ripe fruit accumulation so that a once-over harvest of a higher percentage of ripe fruit can be made as much a five to seven days earlier than normal.

2. It reduces the amount of green fruits that may need to be sorted on the harvester.

3. It aids in spreading out the harvest schedule if properly planned and with the aid of processor's field staff.

4. It permits late plantings to be harvested before frost.

5. It usually increases yields from fields suffering from split-set conditions.*

6. It helps overcome the delayed ripening of fields with excessively vigorous plants.

*Split-set means that certain environmental conditions, especially high temperature, have caused some flowers to fail to set fruit during the bloom period. This results in uneven maturity that seriously affects yields from a once-over harvest.

Time of Application

Ethephon is effective only in ripening fruits that have reached the mature green stage of development. It has little or no ripening effect on fruits that are immature or in which the coloring process has already been initiated. The objective, therefore, is to have the maximum number of fruits on the plants at the mature green stage at the time of treatment. With most of the processing varieties, this occurs when 5 to 30 percent of the fruits on the plants are pink or red. Ohio research suggests the greatest response to an ethephon application occurs when 5 to 20 percent of the fruits by count show color.

To determine the mature-green stage, several fruits should be cut with a sharp knife. If the seed cavities are filled with gelatinous pulp and the seed coat is tan or brownish, the fruits are considered mature. Mature fruits also show a slight color change from green to light green or white. Processing company representatives should be consulted when determining maturity, because newer varieties vary in internal characteristics and color. The average time of harvest is 14 to 18 days after treatment.

Effectiveness of an ethephon application also is influenced by the plant condition at the time of application. Plants that are wilted due to water stress will likely not respond satisfactorily. If plants are in a wilted condition, even though the fruits are at the proper stage of maturity, delay application until after a rain (or irrigation) and the plants have returned to a normal turgid condition. Furthermore, applying ethephon when plants are wilted will likely cause defoliation, depending on the temperature.

Rate of Application

Label recommendations are to use 3¼ pints of the commercial 2-lb-per-gal ethephon formulation per acre (0.8 lb ethephon) under normal conditions in Ohio. However, under cooler temperatures late in the season, use up to 6½ pints per acre (1.6 lb ethephon) because absorption is less at lower temperatures (Fig. 11). Also, 0.4 lb per acre (1⅝ pints) may be sufficient for early maturing varieties that are less vigorous or mature when temperatures are high and the rate of absorption is high. Do not use rates above 6½ pints per acre at any time because of excessive residues of the chemical. Furthermore, excessive rates will cause defoliation that will result in reduced fruit quality (Table 3).

Remember that ethephon initiates ripening and has little, if any, effect on rate of ripening. Temperature has the greatest influence on rate of ripening after it has been initiated. Do not increase the rate of application, expecting

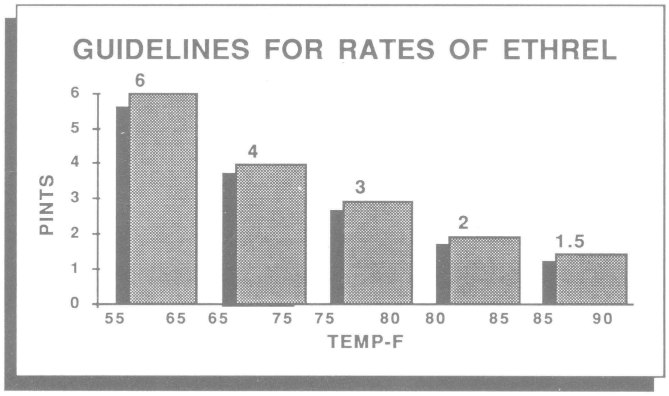

Fig. 11: Temperature influences the rate of Ethrel application.

Table 3: The Effect of Ethephon Rate and Simulated Excessive Rates (Defoliation on Fruit Quality and Yield)

Rate	Ripe (T/A)	Yield Green (T/A)	Total (T/A)
Untreated	19.0	4.1	23.1
Ethephon 3¼ pt	21.5	2.2	23.7
Ethephon 1 gal	21.2	1.1	22.2
Ethephon 2 gal	21.4	0.6	22.0
Remove 50% leaves	20.4	3.8	24.2
Remove 90% leaves	15.7	1.7	17.4
LSD 5%	3.1	1.1	3.7

to increase the rate of ripening. The rate of application should be governed primarily by the air temperature at the time of application and expected temperature during the next 2 or 3 hours. (See the section on temperature effect.)

Uniform and adequate coverage of the fruits and vines is essential, regardless of the rate of material used. Forty to 80 gallons of spray solution per acre usually gives good coverage depending on foliage density and type of sprayer used. Boom-type sprayers appear to provide the more desirable spray coverage, although ethephon has been satisfactorily applied with properly adjusted and operated air-blast sprayers. Some applicators have improved coverage with air-blast sprayers, especially in heavy vine growth, by making two passes over the treated area, the second pass being perpendicular to the first. However, be sure to reduce the material added to the spray tank to one-half so as not to exceed the desired final rate by the double spraying. Also, be sure the second pass is made as soon as possible following the first, preferably before the first has dried completely. If not, the effectiveness may be reduced significantly.

Aerial applications with spray rates of 10 to 15 gallons per acre provides satisfactory coverage under most aerial application conditions in Ohio. The higher rate should be used on most field-seeded plantings and on varieties and plantings with dense foliage.

Ethephon not only promotes fruit ripening, but initiates aging and senescence of leaves. If plants are under stress at the time of application, severe leaf yellowing and eventual drop will likely result. Moisture stress, disease, insect or hail damage, low plant vigor due to root damage, or insufficient available nutrients will increase the foliage injury. Loss of foliage may be beneficial for mechanical harvest but may also expose the fruits to high sunlight, which may result in poor color development. Leaf effects will occur regardless of rate used, but will be more severe at higher rates and under high temperatures. When temperatures are in upper 80s and 90s, defoliation can be very serious. Further, transplanted plants will usually show more loss of foliage than seeded plants.

Temperature Effect

Temperature influences absorption and translocation of the chemical. In general, the higher the temperature immediately following application, the greater the rate of absorption and the greater the effectiveness of the chemical. The temperature at the time of application should be above 65°F, and the temperature should be rising. Absorption of ethephon is very slow at temperatures below 65°F. **Do not use when temperatures of 90°F or above are expected during the 24 to 48 hours following treatment.** At high temperatures, this practice should be followed for three reasons: 1) the plants probably are under moisture stress, 2) the ripening response will not be as favorable and 3) more leaf damage will occur.

High temperatures hasten natural fruit maturity and ripening and cause a general reduction in plant vigor. Therefore, response to ethephon applications made at relatively high temperatures will be accelerated. Fields should be watched closely, and growers should be prepared to harvest when the fruits are at the correct degree of ripeness.

Rainfall Effects

After application of ethephon, a period of three hours is necessary for adequate absorption. If rainfall occurs before the three-hour minimum time, the area cannot be treated again; re-treatment is not permitted under the label restrictions. Keep your delivery schedule in mind to determine the area to be treated. **Note: It is possible to get response from an application that received rainfall within the three-hour minimum time.**

Variety Response

Most current tomato varieties respond to ethephon application. Differences may occur between early and late-maturing varieties. These differences may be more closely related to temperature conditions at the time of treatment, and thereafter, than to the varieties. Differences also may occur between the smaller vine, concentrated fruit-set types and the larger vine types and later varieties. These differences are related to the relative number of mature green fruits on the plants at the time of treatment. Field observations suggest that varieties that have a loose fruit attachment when ripe tend to have more detached fruit after ethephon treatment. Check with your company field person on variety response.

Holding Tank Mixes

It is best to apply the spray mixture as soon as possible after adding ethephon to the water. A few hours delay is probably not serious, but if it becomes necessary to hold the material overnight, discard it and mix a new batch. Proper planning, including attention to weather, will permit application without undue delay.

Mixing with Pesticides

Mixing with herbicides, insecticides or fungicides should be avoided.

Fruit Quality

Ethephon usually has no detrimental effect on fruit quality. However, excessive application may cause defoliation that may result in reduced fruit quality. With proper harvest management, overall fruit quality will improve because treated fields can be harvested early enough to prevent excess overripe, rotted fruits.

On the other hand, there may be more overripe fruit in the load if harvest is delayed beyond optimum ripeness. It is important that the crop is watched closely and harvested at the proper time.

Time of Harvest

Optimum harvest could be 10 to 12 days after treatment for an early season crop and up to 3 to 4 weeks after treatment later in the season. The average interval between application and harvest is 14 to 18 days. Temperature greatly affects these time periods, so be prepared. Work with your processor's field person on when to apply to meet schedule.

Growers should begin harvest before the maximum amount of usable fruit is on the vines. Delaying harvest can result in excessive overripe and rotten fruits in later harvests. Ethephon should not be sprayed on more acreage at one time than can be harvested in 3 to 4 days.

Summary—Do's and Don'ts of Using Ethephon

Do

1. Consider and use ethephon as a tool in a complete management system.
2. Plan ahead and discuss your plan with the processing company field person.
3. Read and follow label instructions—use correct rates.
4. Treat only limited acreage to gain experience.
5. Treat when maximum number of fruits are mature green.
6. Thoroughly cover all fruits and vines.
7. Use the correct amount of chemical3¼ pints per acre.
8. Treat when temperatures are between 75 and 85°F, if possible. If temperatures are cooler, be sure the temperature is "on the rise."

9. Treat when there will be at least 3 hours before a rain.
10. Treat only the amount of acreage that can be harvested in 3 to 4 days.
11. Harvest when fruits are at the correct ripeness.

Do Not

1. Use excessive amounts—3¼ pints per acre are sufficient under all cases except where temperatures are below about 70°F.
2. Treat entire acreage at once.
3. Treat when plants are wilted.
4. Treat when plants are stressed from insects, disease, nutrient deficiency or severe defoliation.
5. Mix with herbicides, insecticides or fungicides.
6. Hold tank mixes overnight or longer than 2 to 3 hours.
7. Expect treatment to accelerate fruit ripening.
8. Treat varieties that normally do not stick on the vine when ripe. Ethephon treatment may increase shattering of fruit.
9. Expect treatment with ethephon to replace good management practices in the entire production system.

Preparation for Harvest

Learn as much about the machine as possible before going to the field. The dealer will provide much useful information. Talk with other farmers who have owned and operated a similar model. Become aware of how the machine will operate in adverse field or weather conditions and be prepared to take proper action. Maintain an inventory of repair parts.

Be sure to clean the machine daily or more frequently, if necessary. Cleaning is necessary in both dry and wet conditions because rotted tomatoes cause mud build-up. After cleaning is a good time for lubrication, inspection and repair of any defective parts. Some operators have been successful in cleaning the machines by dry scraping, while others prefer high pressure liquid or steam cleaning.

Develop an appreciation for the true capacity of the machine in tons per hour. Avoid basing the decisions on the maximum capacity value since maximum values occur only under ideal field conditions. Instead, assume the first half of the crop will be harvested at 50 percent maximum capacity. Harvest crews should improve with proper management, but the average machine capacity is not likely to be higher than 85 percent maximum capacity. Typically, 15 percent of the operating time will be used for rest periods, trailer changes, turns, unplanned maintenance and repair, and other miscellaneous delays.

Discuss delivery schedules with the processor's field representative and have enough trucks and trailers available to keep the harvester operating to meet delivery schedules. A "rule of thumb" is to have the capacity of ½ to 1 ton per acre contracted on wheels. For example, if 80 acres are contracted, wagon and truck capacity for 40 to 80 tons are needed.

Trucks and large semi-trailers can be maneuvered in the field if it is dry. Large semi-trailers need a 100-plus horsepower tractor hitched to a tandem axle fifth wheel. Under wet conditions, large trucks must be parked outside the field. Tomatoes may be delivered to the truck with scissors lift or dump cart trailers (Fig. 12). Two of these

Fig. 12: Field wagons or dump cart trailers for harvesting tomatoes.

trailers are necessary. All wagons and trailers should have wheels spaced the same as the row spacing. This is especially important when opening fields.

Open fields from the center and work toward the inside of the field. When the turn-around time becomes too long, open up the center again. Allow approximately 35 feet at the ends of the rows to turn around without backing.

The technology of sorting green or rotten tomatoes and trash is changing rapidly. Automatic or electronic sorting devices are available that reduce hand sorting. Growers purchasing machines for the first time should thoroughly examine all information before purchasing an automatic sorting system.

Some processors may accept loads with minimum field sorting because they do some in-plant sorting at the receiving station. Some field sorting will likely be necessary regardless of the type or age of harvester purchased. Consequently, a crew will probably be needed for the harvesting operation.

The trucks and wagons used to transport the fruit to the processor's receiving station should have tight beds to prevent juice leakage on the highway.

Selecting and Training Sorters*

*Some of this information is borrowed from the University of California, Leaflet 2686, "Mechanized Growing and Harvesting of Processed Tomatoes."

Most workers will do a better job if they recognize the importance of the job. For best worker efficiency, each crew member should not only be told how to do the job, but why it should be done in a particular way. Explain to them the grading standards that are being used by your processor and explain why poor sorting can cause rejected loads.

Select sorters carefully and in advance. They will represent the major part of your crew. Consider the need for having people for the entire season. Also consider methods of payment, pay scales and incentives. Additional benefits such as a handy source of good, cool drinking water and scheduled rest periods can make for good employee relations.

Four Steps in Training Workers

1. Prepare the worker. Emphasize the importance of the work. Find out how much the worker knows about the job.
2. Teach the worker the job. Explain one step at a time. Stress key points. Stress safety. Tell, show, illustrate, explain, and then question workers to be sure they understand. If you have a problem with grade, take several key workers to a grading station to talk with the inspector on grade requirements.
3. Try out the workers. Let workers do the job; correct workers if necessary. Accuracy is most important at the beginning; speed will develop.
4. Follow up. Put workers on the job. Check them occasionally. Encourage them to ask questions. Keep in touch with the foremen because workers may need help and understanding.

Remember, workers have not learned if the instructor has not taught.

Train workers with actual fruit that demonstrates acceptable grade. Also, identify any defect-type fruit that must be sorted. Stress the importance of safety while the machine is operating.

It is best to assign sorters to "stations" along the conveyors. Each station has a specific assignment. For instance, station 1 can remove overripe; station 2, clods; station 3, greens; and station 4, other defects. The number of sorters in each station will depend on the field and crop conditions. Keep the work load even among sorters by rotating positions regularly or at the end of a specific number of rows. Try to flip or throw discarded fruits only a short distance. Train sorters to sort with both hands. When two hands are used, output increases 25 to 50 percent. Warn sorters not to discard acceptable fruit just to appear busy.

Designate one person as a sorting supervisor. This person should be located at the loading elevator. The supervisor may hire or fire sorters, determine payroll information such as time keeping and train sorters to improve their efficiency. If one person is given this responsibility, it relieves the operator and grower of the sorting burden, providing a continuous check on sorting efficiency. Some growers even allow the supervisor to determine machine speed because he or she is in a position to see the flow of fruit passing each sorter.

The supervisor should be encouraged to watch sorters carefully to determine if the sorting is being done properly. To determine if too many culls are going into the bin or truck, take a sample at the discharge point and examine for percentage of culls.

The need to mechanize, however, is here and now. It will continue to be essential that much planning precede the actual operation of the machine. The successful grower always has a well devised contingency plan for the unusual or problem year.

Explanation of Budgets Receipts

Yield Levels

The budget shows three yield levels: 20, 25 and 30 tons per acre (Table 4). Many farmers in Ohio are achieving yields above 30 tons, but there also are yields less than 15 tons each year. The 25 ton level is near the state average of recent years.

Price for Tomatoes

The $63 price level is not to predict or dictate the price level of 1988. There will be, as normal, a variation in prices paid for tomatoes in Ohio. Part of this price variation is explained by different grade standards, by different receiving procedures among companies, and by the competitive market situation.

Variable Costs

Plants

The 11,500 plants per acre may be a little higher than most farmers are setting. One reason for this higher figure is to allow for any replanting costs that farmers might experience. The price of plants vary and $15 per thousand represents an expected average cost for 1988.

Field seeding of machine-harvested tomatoes is possible and actually can result in a lesser total cost. One fear about field seeding is the possibility of not getting a stand. Budgets show that field seeding competes very favorably with the transplants, even considering the higher risk of replanting.

Fertilizer

The quantities of fertilizer varies from field to field depending on soil tests, prior crops, yield goals, etc. A consistent thought throughout the industry is that nitrogen fertilizer on machine-harvested tomatoes should be limited to enhance uniform ripening. The price of nitrogen is listed at $.14 per pound of actual N, an estimated cost for the forms of nitrogen used on tomatoes.

Chemicals

The herbicide, fungicide and insecticide programs vary tremendously from season to season, processor to processor and from farm to farm. Many combinations of sprays are being used over Ohio.

The use of Ethephon has been one of the management practices that has improved the success of machine harvest. The recommended application rate for Ethephon varies from 2 to 6½ pints per acre with the higher rates being used later in the season.

Table 4: 1988 Processing Tomato Production Budget—Machine Harvest

Item	Explanation	Price per Unit	Yield/Acre[1] 20 T	25 T	30 T	Your Budget
Receipts		$63.00/T	$1260	$1575	1890	$
Variable Costs						
Plants	11500	15.00/M	173	173	173	
Fertilizer[2]						
Starter (10-34-0)	5 gal	1.10/gal	6	6	6	
N	60 lb/A	0.14/lb	8	8	8	
P205	175 lb/A	0.17/lb	30	30	30	
K20	275 lb/A	0.09/lb	25	25	25	
Lime	1000 lb	14.00/T	7	7	7	
Chemicals[3]						
Herbicide						
Sencor-Lexone	1.5 lbs	19.00/lb	29	29	29	
Treflan	0.25 gal	26.50/gal	7	7	7	
Fungicide						
Copper	1 gal	6.20/gal	6	6	6	
M45	18 lbs	1.70/lb	31	31	31	
Bravo 500	2 gal	25.85/gal	52	52	52	
Insecticide						
Sevin 80 S	4 lbs	2.50/lb	10	10	10	
Thiodan 3 EC	0.25 gal	29.00/gal	7	7	7	
Ripener						
Ethephon	0.5 gal/A on 75% of acres	39.00/gal	15	15	15	
Custom Spraying	7 sprays	5.50/A	39	39	39	
Hired Labor[4]						
Setting	13 hrs	3.75/hr	49	49	49	
Hoeing	7 hrs	3.75/hr	26	26	26	
Sorting	20 hrs	3.75/hr	75	75	75	
Crop Insurance		23.00/A	23	23	23	
Inspection		0.30/T	5	6	8	
Fuel, Oil, Grease[5]			30	30	30	
Repairs			51	51	51	
Custom Haul[6]		7.00/T	140	175	210	
Unemployment Ins.	$150/A	3.7%	6	6	6	
Transport. for Labor[7]			5	5	5	
Miscellaneous[8]			7	7	7	
Interest on Oper. Cap[9]		6 months	10%	23	23	23
Total Variable Costs—per Acre[10]			$ 883	$ 919	$ 956	$
per Ton[10]			$44.15	$36.77	$31.86	$
Fixed Costs						
Housing Charge[11]			$ 21	$ 21	$ 21	
Labor Charge	14/16/18 hr	$ 4.50/hr	63	72	81	
Machine/Equip. Charge[5]		$14.00/T	280	350	420	
Land Charge			100	150	200	
Management Charge	5% of Gross		63	79	95	
TOTAL FIXED COSTS			$ 527	$ 672	$ 817	$
Total Costs—per Acre			$1410	$1591	$1772	$
—per Ton			$70.50	$63.64	$59.07	$
Return Above Variable Costs/a			$ 377	$ 656	$ 934	$
Return Above Total Costs/a			$-150	$ -16	$ 118	$

[1]With a mechanical harvestor, the risk of being unable to harvest some acres or loss of quality due adverse weather must be considered. Acres lost due to inability to harvest will increase costs to be recovered from harvested acres and will reduce budgeted receipts by number of tons lost.
[2]Assume maintenance fertilizer only.
[3]Various combinations and kinds of chemicals are used. Other popular herbicides and insecticides are used.
[4]Labor rate includes Social Security and Workers' Compensation.
[5]The machine cost is greater than hand harvest to reflect the operation and overhead expenses of a bedder and harvestor.
[6]Some companies credit the grower for some hauling charges.
[7]1600 miles/4 acres per worker x 75% usage on tomatoes
$0.015 per mile $5 per acre.

Table 4: 1988 Processing Tomato Production Budget—Machine Harvest—(continued)

Item	Explanation	Price per Unit	Yield/Acre[1] 20 T	25 T	30 T	Your Budget

[8]Includes supplies, utilities, soil tests, small tools, etc.
[9]Does not include interest on harvesting costs, inspection cost, plant cost or seed, or hauling cost. Interest costs would be reduced by the interest saved due to any advanced payments received.
[10]If direct seeding is used, deduct plant cost and setting labor costs and add cost of seed, other seeding costs, and changes in herbicide program.
[11]Housing cost: $16,000 value x 20.75% overhead x 75% use on tomatoes $2490. Trash pickup, utilities, land charge, water $898. $898 x 75% usage on tomatoes $674 + $2490 $3164 / 30 workers annual capacity of the housing $105.46 per worker housed for tomatoes. To arrive at the per acre charge, the $105.46 is multiplied by the average number of workers per maching (18) and divided by the acres per maching (90). This yields a cost of $21.10 per machine harvested acre.

Spraying

Seven trips for applying spray were charged to the crop. The number of trips required depends, to a great extent, upon the weather during the growing season.

Labor

The section of the budget that relates to labor expense refers only to hand labor. The labor for operating machines is included as a part of the labor charge under fixed costs. The rate of $3.75 per hour is an estimate of what growers will be paying in 1988. The minimum wage for labor in 1980 is $3.35 per hour.

The $3.75 does include social security and workers' compensation. The social security rate for an employer for 1988 is 6.13 percent. The employees will have a similar cost.

The workers' compensation rate for hand labor is 2.023 percent. Hand labor includes setting plants, sorting and hoeing. The workers' compensation rate for machine operator labor is 6.853 percent and is included as a part of the hourly rate for such labor.

Labor for setting tomatoes was determined by assuming 98 minutes to set one acre of tomatoes and eight people working to keep a three-row planter operating (8 people × 98 minutes = 784 minutes divided by 60 minutes = 13 hours).

Hoeing labor varies considerably depending on the results of the chemical weed control. In 1970 and 1971, farmers were averaging 7 hours of hoeing per machine-harvested acre.

Sorting labor is averaged at 20 hours per acre for all yield levels. Usually the harvester field speed decreases as higher-yielding tomatoes are harvested. Economic studies show that the harvester should not be required to slow down because of a lack of people on the machine. It is cheaper to hire additional labor than to slow down such an expensive machine. In 1978 as few as two sorters and as many as 18 sorters were observed on machines. Several factors affect the number of sorters placed on a harvester. Some of the major factors are include the number of weeds, number of rotten tomatoes, and percent ripe. If processors try accepting more field-run.tomatoes by doing more in-plant sorting, farmers will likely experience less sorting costs than shown in the budget.

Crop Insurance

The rate being quoted for crop insurance by private companies is $23 per acre of coverage. If a farmer does not carry insurance through an outside insurer, he has actually chosen to insure himself. When a loss is encountered without an outside insurer, it is amortized over the year of loss plus years of no loss and, in such case, insurance is still a cost to be considered. This insurance entry can be considered risk coverage, be it the risk of drought, hail, excess water, pests or various other factors that might reduce yields.

Inspection Fees

These are fees that are paid to the Ohio Department of Agriculture for conducting the state inspection program.

Fuel, Oil and Grease

The fuel, oil and grease cost of $30 pays for all operations, except hauling of tomatoes to market and the custom spraying. Field operations, which make the fuel for tomatoes greater than for general crops, include bedding, two or three additional cultivations, and additional fuel for harvesting.

Repairs

The $51 repair cost included in the budget pays for all machinery repairs, except those related to hauling. Table 5 contains repair estimates for special field operations: $9.78 per acre for the bedder, $3.68 per acre for the transplanter, and $23.22 per acre for the harvester plus $2.56 per hour for the tractor used to do the added field operations that are not needed for general crop production.

Custom Hauling

An often quoted rate for custom hauling is $7 per ton. This should pay for the truck and labor. If a farmer does his own trucking and owns the equipment, then he will encounter the costs of depreciation, interest on investment, repairs, insurance, housing, fuel, oil, grease and labor. These could well amount to $7 per ton.

Unemployment Insurance

Unemployment insurance must be paid once an employer pays $20,000 in cash wages per calendar quarter or employs

Table 5: Budgets for Specialized Tomato Equipment[1]

Budget for 90 H.P Tractor Used in Specialized Tomato Operations

			Annual Cost		Cost/Hr.
Purchase Price[2]	$ 32,000				
Salvage	−11,050				
Depreciation	$ 20,950	- 7 years =	$ 2,993	- 500 hrs =	$ 5.99
Interest[3] $\frac{\$32,000 + \$11,050}{2}$ =	21,525	× 12% =	2,583	- 500 hrs =	5.17
Repairs	32,000	× 4% =	1,280	- 500 hrs =	2.56
Insurance	32,000	× 0.2% =	64	- 500 hrs =	.13
Housing	32,000	× 0.7% =	224	- 500 hrs =	.45
Totals			144		$ 14.30
Fuel, Oil and Grease					
9 gal of fuel per hour x 90c + 10c per hour for oil & grease				=	$ 9.00
Total Cost of Operation per Hour					$ 23.30

Budget for Power Bedder

			Annual Cost		Cost/A
Purchase Price[2]	$ 22,000				
Salvage	−6,000				
Depreciation	$ 16,000	- 7 years =	$ 2,286	- 90 A =	$ 25.40
Interest[3] $\frac{\$22,000 + \$ 6,000}{2}$ =	14,000	× 12% =	1,680	- 90 A =	18.67
Repairs	22,000	× 4% =	880	- 90 A =	9.78
Insurance	22,000	× 0.2% =	44	- 90 A =	.49
Housing	22,000	× 0.7% =	154	- 90 A =	1.71
Totals			$ 5,044		$ 56.05
Tractor for bedding $18.56 per hour @2 acres per hour				=	$ 9.28
Labor for bedding $4.50 per hour 2 acres per hour				=	2.25
Tractor for cultivating with bedder $18.56 per hour 1-1/2 A/Hr				=	12.37
Labor for cultivating with bedder $4.50 per hour 1-1/2 A/Hr				=	3.00
Total cost of bedding, including 2 cultivations with bedder				=	$ 82.95

Budget for Transplanter Cost

			Annual Cost		Cost/A
Purchase Price[2]	$ 7,000				
Salvage	−2,050				
Depreciation	$ 4,950	- 10 years =	$ 495	- 76 A =	$ 6.51
Interest[3] $\frac{\$ 7,000 + \$ 2,050}{2}$ =	4,525	× 12% =	543	- 76 A =	7.14
Repairs	7,000	× 4% =	280	- 76 A =	3.68
Insurance	7,000	× 0.2% =	14	- 76 A =	.18
Housing	7,000	× 0.7% =	49	- 76 A =	.64
Total				$ 1,381	$ 18.15

Budget for Tomato Harvester

			Annual Cost		Cost/A
Purchase Price[2]	$150,000				
Salvage	− 59,000				
Depreciation	$ 91,000	- 7 years =	$13,000	- 90 A =	$144.44
Interest[3] $\frac{\$150,000 + \$59,000}{2}$ =	$104,500	× 12% =	540	- 90 A =	139.30
Repairs	150,000	× 2% =	3,000	- 90 A =	33.33
Insurance	150,000	× 0.2% =	300	- 90 A =	3.33
Housing	150,000	× 0.7% =	1,050	- 90 A =	11.67
Total				$29,890	$332.07

Table 5: Budgets for Specialized Tomato Equipment[1]—(continued)

Fuel, Oil and Grease		$ 10.00
Operator Labor Cost		
8 hr of machine operation per day		
× 2 operators		
16 hr		
+ 2.8 hrs per day for cleaning and maintenance		
18.8 hrs x $4.50 per hour	$84.60 per day - $4.73 A per day=	$ 17.89
Tractor cost 1.5 hrs per acre x $18.56	=	27.84
		$387.80

[1]The rates of performance for each the bedder, transplanter and harvesters are based on information learned during the 1970)71 mechanical tomato harvester study.

Ninety acres are used as a base for the harvester. If 4.73 acres are harvested per day, 90 acres will require 19 days. Nineteen days was the average for harvesters to be operated in 1970-71.

The transplanter was assumed to be limited to 76 acres each year. If the transplanter operates an average of 8 hours each day during the planting season and it takes 95 minutes to plant an acre, then 15 days would be used to plant 76 acres.

[2]The purchase price of machinery is quite variable. For example, there are power bedders, sled bedders, new bedders and used bedders; or there are self-propelled harvesters, pull-type harvesters; new harvesters and used harvesters and also different makes of each type of machine. The purchase prices entered approximate an average of what a farmer might have to pay in 1980.

[3]The interest calculation first determines the average value of the machinery for the period of ownship and then multiplies that average value by the current interest rate.

ten or more employees in each of 20 or more weeks. If a farmer has once become subject to unemployment insurance, he cannot stop paying until he experiences an entire year without wages.

Transportation for Labor

Several farmers pay transportation costs for labor as they move from their previous employment to Ohio. This charge was calculated using $.01 per mile × 1,600 miles making $16 per worker. It is assumed the workers work 75 percent in tomatoes and 25 percent in other crops, making the cost to be charged to tomatoes $16 × 75 percent or $12. If ten workers per machine is the average for the season, then the cost to be charged to tomatoes is $120. Using the machine over 90 acres results in $1.33 per acre.

Miscellaneous

The $7 miscellaneous entry allows for such expenses as utilities, soil tests, small tools, record keeping and miscellaneous supplies.

Interest on Operating Capital

Money is expended for several items as the tomato crop is planted and continues to be invested until the crop is harvested and money is received. This money is borrowed, or interest paid or owned capital is used that could have been invested elsewhere with an anticipated return. Totaling the expenses in the budget that are encountered before harvest: plants, $173; fertilizer and lime, $76; pesticides, $157; setting and hoeing labor, $75; crop insurance, $23; fuel, oil and grease, $30; repairs, $51; transportation of labor, $5; miscellaneous, $7. Thus, the total for an operating pre-harvest expense is $642. Most of this money is invested for 6 months, April 15 through October 15, some for a longer and some for a shorter period. (639 × 10% annual rate × (6 months divided by 12 months) = $31.95 per acre.) Some of the expenses listed are advanced to the farmer until settlement with the company. An example would be the cost of transplants. If this is the case, the interest calculation should not include that expense item and would be reduced to $23.30.

Total Variable Costs

The total variable cost represents costs that would not be encountered if tomatoes were not grown. Also, they are costs that would change if the land were used for another crop.

Variable costs tend to be short term and the amount of these costs will not be known until after the decision has been made to grow tomatoes in any one year. This is contrasted with fixed costs, which continue even if tomatoes are not grown or if some crop other than tomatoes are grown. The total variable costs have been estimated at $883, $905 and $956 with the respective yields of 20, 25 and 30 tons per acre, Table ?.

Fixed Costs

Housing Charge

A farmer in northwest Ohio recently made an investment in labor housing. This investment was used to calculate a housing charge.

A total of $16,000 was invested for 30 workers. One group of costs incurred with this type of investment includes depreciation, interest, insurance, repairs and taxes. The initial investment is multiplied by an annual percentage as these costs are amortized over the expected life of the investment.

The estimated annual percentage for each cost item is as follows: depreciation, 12.5 percent (eight-year life); interest, 6 percent (same as the average investment × 10%); insurance, .02 percent; repairs, 2.15 percent; and taxes, .08 percent. This total is 19.75 percent. It has been approximated that 75 percent of the time of the employees using these facilities would be spent working in tomatoes.

Other costs annually include trash pickup, utilities, and a land charge These have been estimated at $898.

Applying all of these factors, the annual cost for labor housing would be $41 per acre. ($16,000 investment × 19.75% annual cost × 75% usage on tomatoes + $898 other costs divided 30 workers annual capacity = $108.93 per worker housed for tomatoes.)

To arrive at the per acre charge, $108.93 is multiplied by the average number of workers per machine (18) and divided by the acres per machine (90). This yields a cost of $21.79 per machine harvested acre.

Operator Labor Charge

The operator labor charge is in recognition of the labor required for all machine operations, except hauling of tomatoes and spraying. The labor for hauling and spraying is a part of the custom charge. Also included in the operator labor is the time spent for purchasing supplies and making repairs. The number of hours of operator labor have been increased from 14 to 16 to 18 hours per acre as yields increased from 20 to 25 to 30 tons.

Machinery and Equipment Charge

The $14 equipment charge per ton recognizes the harvester, transplanter and bedder costs plus costs of tractors, tillage equipment, cultivators, sprayers, pickups, wagons, etc. The $280, $350 and $420 is much higher than the $43 machinery charge that has been budgeted for hand-harvest tomatoes (see also—Table 5).

Land Charge

The land charge of $100, $150 and $200 per acre approximate the cash rent being paid. It is felt by most landowners that specialized crop production results in most trips over the field and more soil compaction than for general crop production. Also, most landowners feel that the better land is devoted to the specialized crops. These two factors represent the reasoning for higher rent charges for the tomato crop.

It is obvious that the $100, $150 and $200 for rent does not generate enough to pay for the $1,500 plus land prices prevalent in the tomato producing area of Ohio. Part of current land price must be allocated to speculation. If a land rent of $150 is considered and $15 per acre is spent for real estate taxes, insurance and the fixed costs associated with tile and other improvements, then $135 remains for an interest return to the land investment. On $1,500 land a $135 net cash rent yields a 9 percent annual return to the land. If a landowner strives for a 12 percent annual return from a land investment the remaining 3 percent would need to come from annual appreciation.

No cost is itemized for principal payment. Principal payments on land, a non-depreciating asset, add to net worth and are not a cost of production.

The increasing land charge with increasing yields is to recognize the difference in quality of land. Part of the yield differentials that occur are because of land quality.

Management Charge

The management charge is in recognition of the role of decision making. Labor in the budget to this point has represented an amount for employing machine operators, sorters, people to transplant and hoe. The management charge is to recognize marketing responsibilities, employer duties, purchasing decisions, and the role of choosing among cultural practices.

The rate of management compensation is calculated at 5 percent times the gross income. For comparison with another crop, a corn crop grossing $220 has an $11 management charge contrasted to the $70 for a $1,400 tomato crop.

Total Fixed Costs

Basically, fixed costs are costs that will continue whether tomatoes are grown or not. Also, these costs will continue if crops other than tomatoes are grown. For example, most of the housing costs will continue whether tomatoes are grown or not, even the management charge could be thought to continue since the ability to grow tomatoes is possessed by the farmer. On a year-to-year consideration of crop production, the fixed costs should not affect the decision of which crop to grow. Fixed costs are an important consideration when making potentially long-term decisions like a land or tomato harvester investment.

Return Above Variable Cost

This calculation was made by subtracting the total variable cost from the gross receipts. This is the most important item of information in the budget. Since fixed costs continue whether a crop is grown or not, and regardless which crop is grown, maximizing the returns above variable costs maximizes returns to the fixed costs. This type of thinking yields the greatest profits.

Return Above Total Cost

In the long run there needs to be a return above the total cost of production. The considerations of profitability for assets with more than a one-year life is best done at the time of purchase of the asset. After long-term assets are purchased, the return above variable costs are of upmost importance unless liquidating an asset is one alternative.

Cost of Production Versus Risk of Production

Identifying the fixed and variable costs associated with producing processing tomatoes enables a grower to construct a production budget for their own operation. Once done, the impact on expected profit of higher/lower yields, selling prices, or input costs can be quickly calculated. As a grower looks ahead to next year's growing season, these calculations provide information on expected costs and returns under the best of growing and harvesting conditions or the worst.

However, there is only a small probability that one of these extremes will occur next year. As a result, additional information is needed on the expected profitability of growing tomatoes under the "most likely" conditions ("most likely" reflects the historical average plus an estimate of the likely variation about the average). The value of this approach lies in the fact that a large number of possible growing and marketing conditions are used to evaluate the risk of production; that is, the probability that returns will exceed variable or total costs.

Using a microcomputer program titled "Risk Analysis Model," expected returns over total costs were calculated for various levels of average yield and expected selling price, Table 6. These results are subject to the following conditions: 1) yields are likely to vary plus-or-minus **three tons** per acre around the average, 2) selling price is likely to vary plus-or-minus **5 percent** around expected, and 3) **zero** profits per acre are required over total costs.

Table 6: Expected Returns and Degree of Production Risk

Return Over Total Costs:

Price/Ton	Average Yield 20 T/A	25 T/A	30 T/A
$60.00	$-206	$-90	$ 29
$63.00	-149	-19	114
$66.00	- 92	52	200

Probability of Returns Covering Total Costs:

Price/Ton	Average Yield 20 T/A	25 T/A	30 T/A
$60.00	1.47%	19.8%	59.86%
63.00	7.52%	43.65%	81 84%
66.00	20.63%	66.62%	92.94%

Under these conditions, positive profits are expected with yields of 30 T/A and prices above $60/T or yields of 25 T/A and prices at $66/T.

Alternatively, at 25 T/A and a price of $66/T there is a 66.62 percent chance that returns will exceed total costs. If average yield increases to 30 T/A, then there is a 92.94 percent chance that returns will exceed total costs.

By reducing the variability/uncertainty in yield per acre from three tons to one ton, there is an **increase in production risk** (probability that returns will exceed total costs declines) for those yield/price combinations that do not cover expected costs, Table 7. For those yield/price combinations that do cover expected costs, there is a **reduction in production risk** as yield uncertainty is minimized. This finding has implications for strategy formulation. Basically, if a grower is in a profitable position, there is an incentive to minimize their exposure to wide swings in yields or prices. If a grower is in an unprofitable position, this exposure works in their favor.

Table 7: Expected Returns and Degree of Production Risk

Return Over Total Costs:

Price/Ton	Average Yield 20 T/A	25 T/A	30 T/A
$60.00	$-206	$-90	$ 29
$63.00	-149	-19	114
$66.00	- 92	52	200

Probability of Returns Covering Total Costs:

Price/Ton	Average Yield 20 T/A	25 T/A	30 T/A
$60.00	0 13%	12.33%	62.54%
63.00	1 43%	41 30%	88 28%
66 00	10 23%	72 89%	97 48%

The model was recalculated with a profit requirement of $100 per acre over total costs, Table 8. The impact of this requirement was to reduce expected returns over total costs by $100 per acre and increase production risk for all yield/price combinations. Given this profit requirement, and a minimal acceptable level of risk at 60 percent, many of the acceptable levels of production in Tables 6 and 7 have become excessively risky.

Table 8: Expected Returns and Degree of Production Risk

Return Over Total Costs:

Price/Ton	Average Yield 20 T/A	25 T/A	30 T/A
$60.00	$-306	$-190	$-71
$63.00	-249	-119	14
$66.00	-192	-48	100

Probability of Returns Covering Total Costs:

Price/Ton	Average Yield 20 T/A	25 T/A	30 T/A
$60.00	0.13%	3.52%	27.43%
63.00	0.80%	14.95%	54.77%
66.00	4.37%	35.21%	77.00%

Summary

Producers of processing tomatoes must be aware of their production costs in order to effectively manage their operations and plan for the future. By calculating next year's expected profits under optimistic and pessimistic conditions, additional information is generated about the possible extremes that may occur. Finally, by simulating a large number of outcomes given before estimates of likely variation in either yield or selling price, an estimate of the riskiness of production can be generated and compared to an individual's personal degree of risk preference.